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2. Patent application number *(The Patent Office will fill in this part)* — 0218598.1 — 12 AUG 2002

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   QINETIQ LIMITED

   Registered Office 85 Buckingham Gate
   London SW1E 6PD
   United Kingdom

   Patents ADP number *(if you know it)* — 8183857001

   If the applicant is a corporate body, give the country/state of its incorporation — GB

4. Title of the invention — Temperature Responsive Connector

5. Name of your agent *(if you have one)* — Bowdery Anthony Oliver

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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   IP Formalities
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Country	Piority application number *(if you know it)*	Date of filing *(day / month / year)*

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11. I / ~~We~~ request the grant of a patent on the basis of this application.

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DUPLICATE

Temperature Responsive Connector

The present invention relates to the use of shape memory alloys in the construction of temperature responsive connectors, which are designed to disconnect on being exposed to a pre-determined temperature. A particular application for such a connector is for a munitions casing in order to help avoid or at least to mitigate an explosive reaction when such munitions are inadvertently exposed to fire or some other source of heat.

By the term "munitions" as used hereinafter is meant a bomb, warhead or rocket motor or any similar device which contains a gun propellant, a rocket propellant an explosive or other energetic material housed within a casing.

The present invention is concerned particularly with the use of shape memory alloys (SMAs) as providing means for mitigating against the violent explosive reaction of a munition when it is heated to the ignition temperature of the energetic material. The worst condition occurs when the rate of heating is very slow, the so-called "slow cook-off" condition. Under these circumstances, the whole munition reaches an almost uniform temperature so that the casing surrounding the energetic material is unlikely to lose very much strength before the point at which the energetic material finally ignites. At this point there is a rapid pressure build-up and a high order explosion or even a detonation occurs. Faster heating, which occurs for example when the munition is exposed to a fuel fire (a so-called "fast cook-off" condition) is less hazardous. In this situation, because the flow of heat is from the outside of the munition to the inside, the casing will reach a higher temperature than the energetic material and so will weaken before the energetic material ignites. It is possible to enhance this effect by choice of case materials and by the use of thermal insulation (which is usually needed anyway) between the case and the energetic material. Although the present invention is concerned with mitigating both fast and slow cook-off, the emphasis is on the latter because of the lack of alternative measures for meeting this situation.

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There have been a number of disasters over the last 40 years, involving aircraft carriers, magazines and weapon storage depots in which much loss of life and military equipment have been incurred. Alarmingly many of them have occurred during peace time.

Slow cook-off events have typically occurred where there is a fire in a compartment next to a magazine, which burns for many hours with the result that the magazine heats up slowly and all the explosive stores within it increase in temperature very slowly and uniformly. Therefore, when the first particle of energetic material reaches its spontaneous ignition temperature (T of I), probably in the range 130°C to 200°C, the remainder is also on the verge of igniting. Furthermore, at that temperature the munition casings would retain nearly all of their strength, particularly if they were made of steel. The result can be a high order explosion that can, for example, destroy a ship. Two famous examples of disasters initiated by fires are HMS Sheffield in the Falklands War and the USS Forrestal in the Vietnam War, both of which resulted in large casualties and loss of platforms and systems and munitions

As a result of these and other incidents, the subject of Insensitive Munitions (IM) has become an important one in the design, procurement, storage and deployment of any weapon that employs propellants or explosives, that is most weapons. There is now a general requirement to design main charges, booster charges, explosive trains, rocket motors and gun propellant charges such that when exposed to a disruptive threat they respond as benignly as possible. Therefore, ideally they should give rise to a burning reaction, rather than a high order explosive event or a detonation. In this way it is hoped to avoid the generation of a shockwave or of damaging fragments that would adversely affect other weapons stored in the proximity. By so doing, the hope is that fratricidal events or "chain reactions" can be avoided.

One way to achieve such IM status is to develop propellants and explosives that are relatively insensitive to shock and fragment attack and much work has been carried out on this over the last 25 years, with new generations of energetic materials emerging, albeit slowly,

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Another approach is to design the hardware items, i.e. rocket motor or warhead casing, so that when they are attacked they break open readily and do not allow a rapid pressure build-up that might lead to a detonation or high order explosive event. To some extent, it is difficult to reconcile this requirement with the need to withstand rough handling. Nevertheless some satisfactory compromise solutions have been achieved.

There are several standard IM tests, of which three of the most commonly used are:

- Bullet or fragment impact
- Fuel fire (so-called fast cook-off)
- Slow cook-off (SCO)

These tests are designed to replicate the common threats that may cause premature, unwanted, detonation of munitions. Methods have been devised for combating the first two of these threats, but mitigating against slow cook-off has remained an intractable problem.

Previously a number of methods have been suggested for attempting to mitigate against premature detonation of munitions under slow cook-off conditions. These have included:

1. The use of line cutting charges on the outside surface of the case, and pointing inwards, in association with an appropriate sensor to cut a slit in the case just before the propellant ignites.

2. Thermite blocks have also been used to achieve a similar result by burning a hole in the case.

3. Low melting alloys or polymer compositions have been considered as a means of greatly reducing the strength of a joint when subject to heat.

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None of these methods has proved particularly successful whether applied to rocket motor cases or to other types of munition. The first two methods are considered as active mitigation methods, which involve the use of additional energetic materials on the body of the weapon, which can introduce a further set of hazards making them an unattractive solution. The third method is referred to as passive mitigation. However, the problem encountered with this type of passive mitigation, using low melting materials, is trying to achieve sufficient strength under normal firing conditions, whilst trying to ensure that most of the strength has been lost at the lowest possible propellant ignition temperature, which for a double base propellant could be as low as 125°C. An alternative method, by which a low melting point material is used as a fusible plug is inadequate because it cannot be used to create a large enough aperture for the gaseous products from the propellant or explosive to vent sufficiently quickly.

Shape memory alloys are metal alloys that undergo large dimensional changes when heated or cooled through a particular transition temperature range. Shape memory alloys exhibit two distinct crystal structures or phases and the shape and the mechanical properties of the alloy are different in the two phases. Therefore, upon heating or cooling the alloy, a transition temperature range is reached over which range the crystal phase changes and the alloy will adopt the properties of the new crystal phase. In general, the "memory" is imparted to the SMA by deforming it, usually in the lower temperature state. Therefore a ring which is intended to expand on heating through its transition temperature range would previously have its memory imparted at a lower temperature by compressing it radially. A ring or wire intended to shrink on heating would have the memory imparted by stretching. Materials that exhibit shape memory upon heating or cooling in a manner that is effectively irreversible are referred to as having a *one-way shape memory*. Materials which can alternate between the two states throughout a number of heating and cooling cycles are referred to as having a *two-way shape memory*. However with these alloys the amount of this reversible shape change is usually less than that obtained with an alloy which exhibits one-way memory. In general, though unlike low melt metals, which are mechanically weak, SMAs have mechanical properties that are comparable with those of engineering materials such as light alloys and steels and are therefore ideally

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suited to high stress and strain applications. The transition temperature can be selected by the appropriate choice of composition of the SMA.

The recovery strain achievable by a SMA is typically of the order of 5%. In general, the highest recovery strains are achievable in rings or tubes in which the memory is imparted by stretching in a radial direction and which then shrink to their original dimensions on heating. In the reverse mode, where the memory is imparted by compression and the component expands on heating, the effect is somewhat smaller.

A tube manufactured from a shape memory alloy which is designed to expand radially upon heating will usually contract in length at the same time, as the overall volume of the shape memory alloy remains substantially constant. Likewise, if the tube is designed to contract radially, this will lead to a concomitant expansion along the axis.

US patent no. 6,321,656 discloses the use of shape memory alloys to mitigate against slow cook-off in relation to rocket motors. The patent describes three embodiments of the invention as applied to a rocket motor case, which is in two sections. A first section has a small number of prongs each with a small lug at its tip and the second section has an equal number of recesses for location of said lugs. When the two sections are brought together in an end to end manner the lugs engage with the respective recesses by virtue of the prongs on the first section being biased so as to cause each associated lug to lock with its respective recess in the second section. In a first embodiment of the invention, a shape memory alloy ring, which is of an alloy composition such that upon heating it will contract, is located tightly around the prongs. Upon heating, in a thermal hazard incident, the shape memory alloy ring contracts, pushing the prongs inwards and therefore causing the lugs to move out of the respective recess allowing the two sections of the motor case to disengage and so to vent any built up pressure. In a second embodiment, the shape memory alloy ring is placed on the inside of the prongs on the first section, and is expanded so as to force the prongs into engagement with their corresponding recesses. On heating the ring retracts to its annealed size thereby allowing the prongs on the inner section to move inwards away from engagement with the respective recesses in the outer section. In

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the third embodiment, the first section is slightly modified to allow the location of two shape memory alloy rings, one around the outside and one on the inside of the pronged section, thus providing the combined effects of the first and second embodiments, such that upon heating both rings contract inwards, to give the same overall effect.

However, the arrangement shown in the US patent suffers from the disadvantages that once the ring or rings have been put into position, they cannot be easily removed without heating the device. It is common practice for munitions to be regularly serviced and monitored during their service life and so a non-reversible system such as this would not be an ideal solution. Another disadvantage is that the pronged section produces an internal projection into the volume where the propellant would be located. This results in difficulties for loading the propellant when in cartridge form into the rocket casing and means that the propellant would most likely have to be melt cast. A further disadvantage of the US patent is that the shape memory alloy has to be heat treated to enable the connection means to be installed. In addition, as the whole of the axial load arising from the pressurisation of the case has to be carried through the prongs and lugs, the arrangement is inefficient structurally. Finally, the shape memory alloy ring in this arrangement is not an integral part of the connection system, thus adding to the complexity of the arrangement and hence the cost of manufacture.

Accordingly it is an object of the present invention to provide an arrangement where the casing of a munition that might be subject to a slow cook off situation is caused to disrupt so as to avoid an unwanted detonation of the munition, but whereby the arrangement does not prevent routine disconnection or disassembly of the rocket casing. A further object is to provide a means of disruption which is an integral part of the connection for a munition casing making construction simpler and the casing easier and cheaper to manufacture.

Although this invention is primarily concerned with means for mitigating the effect of slow cook off in relation to munitions it is also recognised that connectors according to the invention may be appropriate for use in other situations. One such area is for the connection of pipes or containers involved in the carrying or storage of

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fluids such as natural gas. In the event of a heating hazard the gas could become highly pressurised, which could cause an explosion. However, the (controlled) release of such a fluid would prevent a violent explosion. The connector in the invention should not be seen however to be limited to use in conjunction with flammable or combustible fluids as any pressurised fluid can present a hazard. Normally the use of such a connector would be in conjunction with other safety mechanisms.

A further use for these connectors would be for the joining and easy release of structural components such as pipes or as for example those used in the construction of oil rigs and which need to be dismantled at the end of their useful life. The underwater support columns of oil-rigs are sometimes cut with explosive charges, but this has adverse effects on marine life. However if these columns were provided with connectors according to the invention, then, at the end of their service life the connectors could be heated (e.g. by a thermal jacket), which would allow the structure to be released and relocated. This could be accomplished without the expense and environmental danger involved in the use of high explosives. Similar arrangements might be contemplated for dismantling of other structures which are difficult and possibly hazardous to access, such as nuclear power stations or chemical manufacturing plants. However, in all these cases consideration would have to be given to situations in which the structures may experience severe temperatures i.e. in a fire hazard situation. Under these circumstances a temperature responsive connector activated by heating would only be appropriate if it could be satisfactorily insulated as otherwise the integrity of the structure might be compromised. An alternative approach to this would be to employ a temperature responsive connector that was induced to disengage by cooling it to a temperature that could never be experienced in normal service (e.g. -50°C).

According to a first aspect of the present invention therefore, there is provided a connection means for joining together separate components to form a unified body wherein locking engagement can be provided between an integral operative part of said connection means and an integral co-operative part of at least one of said components wherein either or both of the operative and co-operative parts is or are made of a shape memory alloy which occupies a first configuration at a first

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temperature and undergoes a change of shape when brought to a second temperature, to afford a second configuration, said operative and co-operative parts providing locking engagement at the first temperature and allowing release from said locking engagement at the second temperature.

Typically, the operative part of the connection means, will comprise a compression fitting, a snap-type of fitting or will involve the use of threaded portions, co-operating with appropriate portions on one or more of the components. The choice of connection means would be dependent on the nature of the two components to be joined and the nature of the situation which the connector is intended to cope with, also whether or not it was desired that the connections should be reversible. The parts made from a shape metal alloy may be pretreated if desired in order to impart a shape memory to the material.

The connection means may form a separate structural and load bearing part between the two components or may form an integral part of either one or both of the components in which said component or components is either wholly formed of a shape memory alloy or has a shape memory alloy insert which forms at least the operative part of the connection means. Furthermore the co-operative parts may both be formed from SMAs wherein one part is designed to expand upon heating and the other part is designed to contract upon heating, therefore affording an increased degree of disengagement. The connection means may be arranged to be either permanent or reversible such that it can be unfastened without being subjected to heat or by cutting or otherwise damaging any of the original components or the connection means, where this is a separate entity. It may readily appreciated that the connection means may possess more than two operative parts, such as a multi-adapter (T - junction connector), in which the connector and components to be joined would possess mutually co-operating coupling locking means.

The separate components may comprise two or more parts of a munitions casing, particularly a rocket motor casing, but may alternatively comprise two or more pipes or columns, which are to be joined together but where it may be desired to achieve the rapid disconnection of the two sections when subjected to a thermal stimulus. In one scenario the stimulus may be from an external hazard such as a fire,

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or secondly the stimulus may be controlled heating to induce failure of the connection means to allow the easy disassembly of a structure. Advantageously such failure can be effected at a remote location such as at a depth underwater or in a hazardous environment such as in a nuclear reactor or in space.

In the context of the present invention the first temperature is a temperature within the range in which the alloy possesses one phase structure and the second temperature is a temperature within the range in which the alloy possesses a different phase structure. The transition temperature for a change in crystal phase (and hence shape) therefore lies between the first and second temperatures.

In the arrangement according to the current invention the connection means can be manufactured from Cu-Al alloys, Cu-Al-Zn, Cu-Al-Ni; Cu-Ni-Al-Zn-Mn or Ti Ni alloys. Small quantities of other components may be used to adjust the transition temperature, for example Nb or Hf may be added to Ti Ni to adjust the transition temperature or achieve better mechanical properties. For the purposes of slow cook-off mitigation, the transition temperature must be higher than the highest temperature incurred in normal service, which may typically be between 50°C and 110°C, depending on the storage and service conditions but below the lowest temperature at which slow cook-off can occur. This cook-off temperature can be as low as 125°C for some classes of propellant but well over 200°C for some pyrotechnic compositions.

Where the connection means comprises a separate load bearing item not integral with either or both of the components to be joined, it may comprise two or more parts, wherein one or more recessed regions, located either internally or externally on the components, can be used to align and locate with the connection means. In this case the connection means has respectively one or more complementary external or internal projections, which when brought into the correct alignment with the two components will engage with the recesses therein so as to lock the parts together. Clearly the alternative configuration is possible, with the projections located on the components to be joined and the complementary recessed regions formed in the connection means. Other combinations and arrangements of this type will be readily appreciated by the skilled person and are to be understood as

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coming within the scope of the invention. The projections can take the form of any protrusion such as a tongue, hooked latch, lug, flange or male thread and the complementary recessed region may, for example, be a pocket, channel, groove or female thread.

In a preferred arrangement where the components to be joined are hollow cylinders, the connection means comprises a separate load bearing member comprising two or more parts and having two internal and/or external threaded portions, arranged to interact with complementary threaded portions on each of the components to form the unified body, such as a munitions casing. The threaded portions at least of the connection means are made from a shape memory alloy which when subject to heating will deform causing the threaded portion of the connection means to contract or expand radially (depending on whether the connection means is located inside or outside the component) and hence to bring about simple disengagement of the thread. Alternatively the disengagement may rely on the concomitent expansion or contraction of the threads parallel to the axis, as the case may be, causing sufficient damage to the threaded portion on the component as to bring about disengagement. In practice it is likely that the disengagement of the two co-operative parts will be afforded by a combination of these two processes taking place.

In a further variant, both co-operative parts of the connection means may be formed from SMAs and be arranged such that, upon heating or cooling as the case may be, one of the threads expands radially and the other contracts radially, to more readily afford separation of the two.

The invention is primarily concerned with the slow cook-off mitigation aspect, however it is not limited in its application to rocket motors or propellant filled munitions, but can be used in conjunction with any container for any energetic material such as a bomb or shell containing high explosive, a torpedo or missile containing propellant or a pyrotechnic device.

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In the case of rocket motor casings, during normal operation of a rocket motor, the temperature responsive connector of the invention must have sufficient structural integrity to withstand the internal pressure generated by the burning propellant. At the same time it must be sufficiently well insulated from the hot gases to remain below its transition temperature throughout propellant burn. Normally a rocket motor has internal insulation to ensure that the case remains sufficiently cool to perform its structural role. If a temperature responsive connector is used, some internal insulation may be required that is additional to the amount that would otherwise be needed. Likewise, if the rocket motor is part of a high-speed missile that is subjected to aerodynamic heating, additional external insulation may be needed to prevent activation of the connector. With the connection means of this invention present, having a transition temperature which is substantially lower than the temperature of ignition of the energetic material, the shape memory alloy will adopt its second configuration under slow cook off conditions before the temperature of ignition is reached, thus allowing the connection means to deform and the missile casing to be disrupted, relieving any build up of gas pressure and thereby preventing an explosion.

In a further application of the present invention a rocket motor casing is engineered completely or partially from a shape memory alloy, wherein the shape memory alloy acts substantially or completely as the connection means. In this arrangement at least one section of the rocket motor casing system is constructed from a shape memory alloy, such that in a thermal hazard situation the second temperature is reached, causing an unlocking action by the deformation of the shape memory alloy rocket motor section in the manner previously described. Thus the component constructed from shape memory alloy may be the cylindrical part of the rocket motor casing or one or more of the end closures.

Another aspect to be considered in the application of the connection means of this invention to mitigation of slow cook off in rocket motor casings is the thermal heating arising in the casing and surrounding structure after the rocket has been fired and the propellant has been consumed. "Heat soak" effects occur whereby heat is transferred from the hotter parts to the cooler parts. The temperature responsive connector, being well insulated, would normally be one of the cooler components, so its temperature would be expected to continue to rise after propellant burn-out.

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Therefore there is the possibility that the connector may disengage at some later stage in the missile flight causing the missile to break apart. Normally, this would be undesirable, and so the insulation provided would need to be sufficient to ensure that this did not happen. However, there are circumstances in which disengagement of this kind would be desirable. For example, with a multiple stage rocket motor, once the rear part of the missile has performed its role it will only contribute to the drag and in this situation, the heat flow into the temperature responsive connector could be arranged to bring about the disengagement of the component parts of the casing automatically at an appropriate point in flight.

In an alternative mode of use of SMAs to effect mitigation of slow cook off, which is applicable in the case of motor tubes or launch tubes, a collar made of solid SMA is placed around the outside of the motor casing or launch tube. The collar is arranged to contract when the SMA passes through its transition temperature range to a sufficient degree to cause the motor tube or launch tube to rupture and thereby to release any pressure build up which may occur prior to an explosion taking place. Typically this arrangement may be suitable for lightweight rocket motor tubes or for launch tubes such as are used in man-portable rocket propelled weapons, eg. man-launched anti-tank weapons.

Yet another alternative mode is to use a collar which is made up of a plurality of windings of an SMA wire. As for the solid collar, the windings contract when the SMA passes through its transition temperature range to a sufficient degree to cause the motor tube or launch tube to rupture. This approach is preferred where the motor tube is thinned ("waisted") on its outer diameter, because with a solid ring it might be impossible achieve a sufficiently tight fit around the motor for the subsequent cutting action to be effective. As overwinding with fibres is a common method of constructing rocket motor cases, it will be convenient also to include SMA wire embodied in the overwinding.

The invention will now be further described with reference to the accompanying drawings in which:-

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Figure 1 is a partial cross section through a connection device according to the invention having an internal thread in conjunction with two sections of a rocket motor casing which possess complementary external threads;

Figure 2 is a partial cross section through a connection device according to the invention having one or more lugs or alternatively a raised annulus, and shows the device in use to join together two pipes or columns which posses complementary recesses;

Figure 3 is a partial cross section through a connection device according to the invention in use to join two pipes, where one pipe has an internal thread and the second pipe has a complementary external thread; and

Figures 4a and 4b are partial cross sections of overwound rocket motor casing having a partial SMA wire overwind.

In the embodiment shown in figure 1 two sections of a rocket motor case are shown at (1, 1a). Each has a threaded portion (2,2a) on its outside face. Connection means (4) is an extended annulus of shape memory alloy, having an internal thread (3) which is complementary to external threads (2, 2a) on the two sections of rocket motor casing (1, 1a). The rocket propellant charge (not shown), will occupy the volume enclosed by the casing. The interface (11) between the two rocket motor sections (1, 1a) is reinforced by respective stepped shoulders (7, 7a) formed on the outside faces of the casing sections. A metal insert (6), which can be of SMA or any material capable of providing mechanical support, is seated against shoulders (7, 7a). Insert (6) may be independent of the connection means (4) or integral with it. To ensure a gas tight seal during normal operation two o-ring seals (10, 10a) are located in the channels (5, 5a) in the respective casing sections.

When subjected to a thermal hazard such that a predetermined temperature is reached, the connection means (4) is arranged to deform, by contraction along its axis plane, causing the internal thread (3) of the connection means to move against and to break the external threads (2, 2a) of the two rocket motor sections as a consequence of which the two rocket motor sections will separate and allow the pressure inside the

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rocket motor to vent. In an alternative arrangement the connector (4) simply expands so as to disengage the threads 3 and 2, 2a respectively, again allowing the motor sections to separate, but in practice it is likely that both mechanisms will operate simultaneously. It will be readily appreciated by the skilled person that the connector 4 could possess an external thread, and that it could be located instead on the inside of the two rocket motor sections (1, 1a) which in turn would possess complementary internal threads. In this arrangement the connector is designed, on being heated, to contract radially with concomitant expansion in the axial plane, thus again affording disengagement of the threaded portions and separation of the two rocket motor sections.

In the embodiment shown in figure 2, two members (14, 14a) which may be cylindrical or of other section and either solid or hollow are to be joined at the interface (17). The connection means (13) is a sleeve of like section to the members having annular projections (16, 16a) which locate into respective recesses (15, 15a) formed in the members to be joined towards the respective ends thereof. (It will be appreciated that the projections and recesses may equally well be continuous, ie. an upstanding annulus and an annular groove or channel respectively and also that the locations of the recess(es) and projection(s) could be reversed). The connected unit 12 may comprise a part of an oil rig or other structure which it is desired to disassemble remotely at some future time. Connecting sleeve 13 is made from an SMA which is shrunken onto the members and is so chosen that on heating to a predetermined temperature it will expand sufficiently to become disengaged from the members (14, 14a) thus allowing them to be separated. It will be readily appreciated by the skilled person that the connecting sleeve can be activated by cooling, which would be more appropriate for any structure that has to meet a fire hazard during service.

In the embodiment of figure 3 two cylinders 18, 19 (which may be either solid or tubular) are to be joined. In this case the connection means is integrated with the members to be joined. Thus cylinder (18) has an internal threaded section (20), while cylinder (19) has a complementary external threaded portion (21). The two cylinders are brought into engagement by screwing them together. At least one cylinder thread (20, 21) is manufactured from a shape memory alloy and may be an inset or

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alternatively one or both of the cylinders may be entirely manufactured from a shape memory alloy. When the connection means is either heated or cooled to a predetermined temperature (as desired), at least one operative part of the connection means (either 20 or 21) is arranged to deform, by either contraction or expansion radially and/or along its axis, causing the threads to disengage and/or be sheared off, as a consequence of which the two cylinders will disengage and be separated. As a variant on this arrangement, both co-operative parts of the connection means may be formed from SMAs and be arranged such that, upon heating or cooling, one of the threads expands radially and the other contracts radially, to more readily afford separation of the two.

In the embodiment of figure 4a there is shown an SMA cutting device. A section of thin walled (typically aluminium) rocket motor case (22) is shown, which has a series of windings of (stretched) SMA wire (24) around one part of the rocket motor case (alternatively (24) could be a solid annulus or collar formed from an SMA). The motor case including the SMA winding or collar (24) is then overwound with a reinforcing wire/fibre (23), which may be an aramid (e.g. Kevlar) or carbon fibre. When the SMA wire (24) is subjected to heating through the transition temperature range of the SMA alloy, the wire (24) will contract along its length and hence the winding will contract radially either simply crushing the rocket motor case or effecting a cutting action into the rocket motor case, and thus causing a rupture (25) of the case (figure 4b), and allowing any pressure inside the case to be released. Similarly with a solid collar or ring of SMA, if previously expanded at the normal working temperature of the munition, this will contract when heated through the transition temperature range for the specific SMA being used.

In certain situations the 'heat soak' effect described previously may be utilised to cause the automatic rupturing of the rocket motor case at an appropriate point in its flight.

Alternatively, the use of an SMA collar or wire overwinding could be applied to a lightweight launch tube for missiles and hence the component 22 in Figure 4 could be such a launch tube instead of a rocket motor case.

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Claims

1. A connection means for joining together separate components to form a unified body wherein locking engagement can be provided between an integral operative part of said connection means and an integral co-operative part of at least one of said components wherein either or both of the operative and co-operative parts is or are made of a shape memory alloy which occupies a first configuration at a first temperature and undergoes a change of shape when brought to a second temperature, to afford a second configuration, said operative and co-operative parts providing locking engagement at the first temperature and allowing release from said locking engagement at the second temperature.

2. A connection means as claimed in claim 1, which is separate from the two components.

3. A connection means as claimed in claim 2, which forms a structural and load bearing joint between the two components when in locking engagement therewith.

4. A connection means as claimed in claim 1, wherein each of the operative and co-operative parts is integral with one of the two components.

5. A connection means as claimed in any preceding claim, wherein only the operative part of said connection means is made of a shape memory alloy.

6. A connection means as claimed in any of claims 1 to 4, wherein said both the operative and the co-operative parts are comprised of a shape memory alloy.

7. A connection means as claimed in any preceding claim, wherein the second configuration is expanded with respect to the first configuration.

8. A connection means as claimed in any of claims 1 to 6, wherein the second configuration is contracted with respect to the first configuration.

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9. A connection means as claimed in claim 6, wherein either the operative or co-operative parts will be expanded in its second configuration and the co-operative and operative parts respectively will be contracted in its second configuration.

10. A connection means as claimed in any previous claim, wherein the operative and co-operative parts respectively comprise either one or more projections and one or more complementary recesses.

11. A connection means as claimed in claim 10, wherein said one or more projections comprises at least one tongue, lug, latch, bolt, wedge, pin, lip, male threaded portion or any other form of protrusion which will form a locking engagement with a complementary recess.

12. A connection means as claimed in claim 10, wherein said one or more complementary recesses comprises a pocket, groove, channel or female threaded portion.

13. A connection means as claimed in any previous claim, wherein the operative and co-operative parts are of circular cross section.

14. A connection means as claimed in claim 13, wherein the operative and co-operative parts possess complementary threads.

15. A connection means as claimed in any previous claim, wherein said connection means reversibly joins the two components, such that the original components and connection means can be recovered.

16. A connection means for joining together separate components to form a unified body wherein said connection means includes an operative part integral therewith and which provides a locking engagement between said components at a first temperature but allows release from said locking engagement at a second temperature, said operative part of said connection means being made of a shape memory alloy which has a first configuration at said first temperature, and a second configuration at said second temperature.

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17. A connection means as claimed in any preceding claim wherein the unified body forms a munitions casing for containment of an energetic material and the second temperature is greater than the first temperature but is lower than the temperature of ignition of the energetic material.

18. A connection means as claimed in claim 17 wherein the munitions casing is a shell, torpedo, missile or rocket motor casing.

19. A connection means as claimed in claim 18, wherein the munitions casing is a rocket motor casing.

20. A connection means as claimed in any of claims 17 to 19, wherein the shape metal alloy has a transition temperature range which lies in the range of 110°C -150°C.

21. A connection means as claimed in any of claims 1 to 12, wherein the components are parts of a structure.

22. A connection means as claimed in claim 21, wherein said components comprise columns of tubular or solid section.

23. A connection means as claimed in claim 22, wherein said columns are of circular section.

24. A connection means as claimed in any of claims 21 to 23, wherein the structure is an oil rig platform.

25. A connection means as claimed in any preceding claim wherein the shape metal alloy is selected from Cu-Al-Zn, Cu-Al-Ni, Cu-Ni-Al-Zn-Mn and Ti-Ni alloys.

26. A connection means as claimed in any preceding claim wherein the shape metal alloy has an expansion/contraction ratio of at least 2%, preferably at least 5%.

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27. A munitions casing comprised of at least two parts connected together by a connection means as claimed in any of claims 1 to 20 or claims 25 and 26 when dependent thereon.

28. A munitions casing as claimed in claim 27 which is a casing for a shell, torpedo, missile or rocket motor.

29. A munitions casing as claimed in claim 27 which is a rocket motor casing or missile casing.

30. A munition comprising a munitions casing as claimed in any of claims 27 to 29 and containing an energetic material.

31. A munition as claimed in claim 30 and comprising a motor unit for a rocket or missile, wherein the energetic material is a propellant.

32. A munition as claimed in claim 30 and comprising a shell wherein the energetic material is a high explosive.

33. An overwound munitions casing incorporating an annulus of a shape metal alloy which has been so treated and which has a composition such that upon heating to a predetermined temperature, said annulus will contract radially inwardly and rupture said munitions casing.

34. An overwound munitions casing as claimed in claim 33 wherein the annulus is comprised of a solid ring of shape memory alloy.

35. An overwound munitions casing as claimed in claim 33 wherein the annulus is comprised of a plurality of windings of alloy in wire form.

36. An overwound munitions casing as claimed in any of claims 33 to 35 wherein the shape metal alloy is treated by stretching or expanding at a temperature below the predetermined temperature.

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37. An overwound munitions casing as claimed in any of claims 33 to 36 wherein the shape memory alloy is selected from Cu-Al-Zn, Cu-Al-Ni, Cu-Ni-Al-Zn-Mn and Ti-Ni alloys.

38. A connection means substantially as herein described and with reference to the accompanying drawings.

39. A munitions casing substantially as herein described and with reference to the accompanying drawings.

40. An overwound munitions casing substantially as herein described and with reference to the accompanying drawings.

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Abstract

The invention provides a temperature responsive connector for mitigating the explosive reaction of a munition when it is subject to an external thermal hazard threat. The connector is at least in part formed from a shape memory alloy, which typically undergo large dimensional changes when heated or cooled through a particular transition temperature range. The connector in this invention is designed to form a locking engagement, between two components of a munitions casing at one temperature, but when subjected to external heating through the transition temperature range will deform to allow the connector to disengage and thus release the two joined components, allowing any build up of pressure to be released quickly. Advantageously if the co-operative parts of the connector and components are threaded portions, then the locking engagement will be reversible. The co-operative parts of the connector may be integral with the components to be connected.

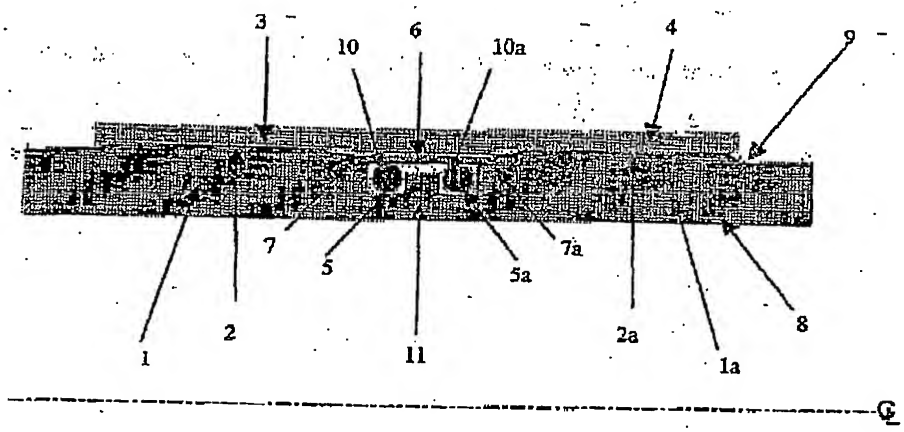

Figure 1

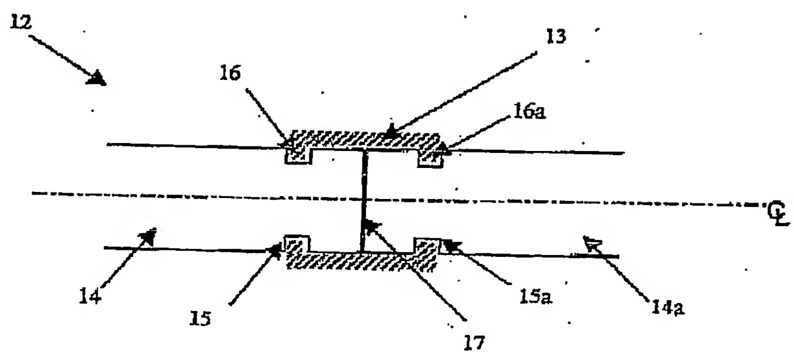

Figure 2

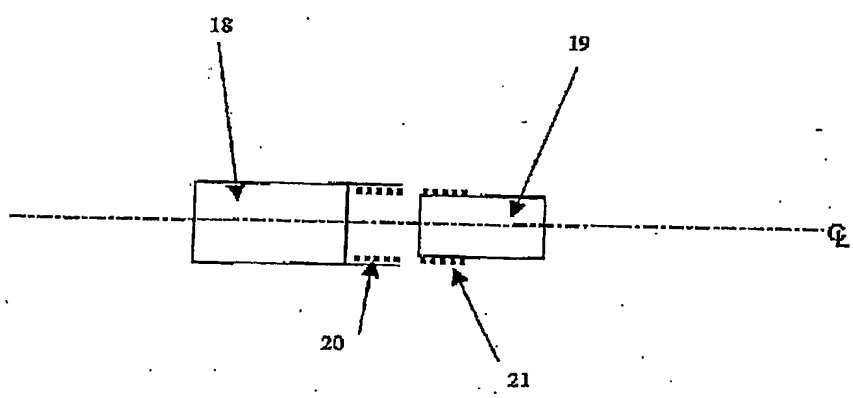

Figure 3

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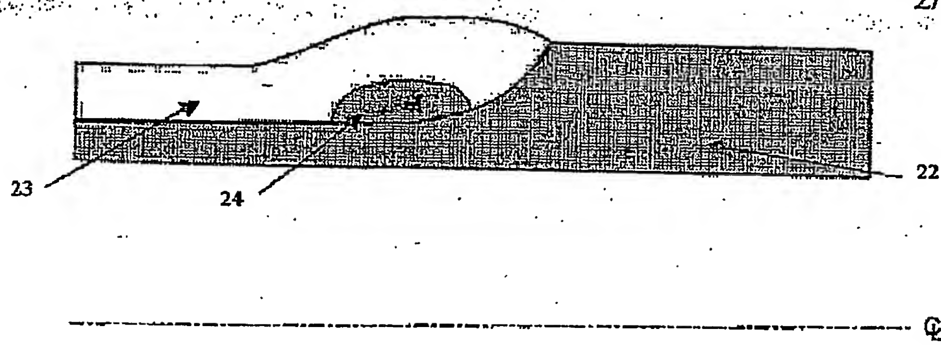

Figure 4a

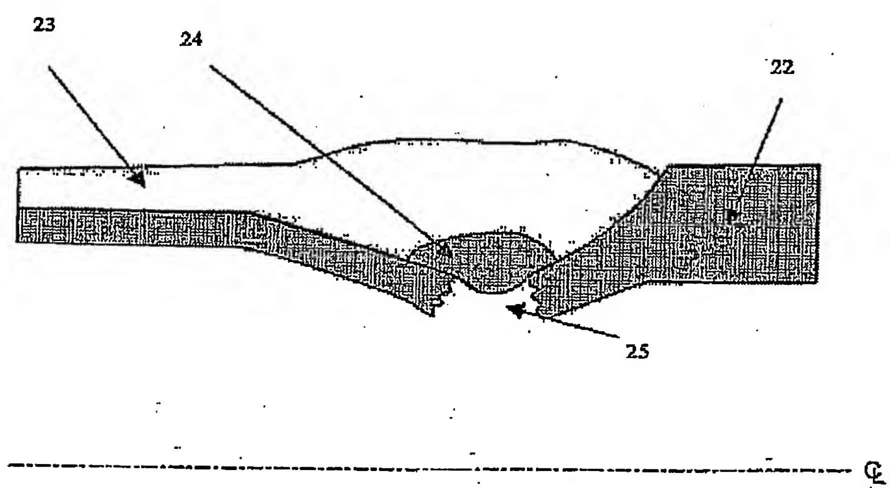

Figure 4b

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